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Title:	Non-Destructive Assay and Measurement Control for Domestic Nuclear Safeguards
Author(s):	Greene, Wilder Robert
Intended for:	Slideshow for guest speaking at Montana State University Bozeman. Audience will be Analytical Chemistry students. Presentation supports discussion of non-destructive assay and measurement/process control.
Issued:	2021-02-09

Non-Destructive Assay and Measurement Control for Domestic Nuclear Safeguards

PRESENTED BY:

WILDER GREENE

Talking points

- Education/Career Background
- What is Non-Destructive Assay?
- What is Measurement Control?
- Examples!

Education/Career Background

- Graduated MSU in Fall of 2013 with a BS in Environmental Science (Soil & Water Science)
- Undergraduate Research Assistant under Dr. Klassen in the Environmental Analytical Laboratory
- Radiological Control Technician at the Department of the Navy
- Industrial Hygienist with the Army Corps of Engineers
- Measurement Specialist with Los Alamos National Laboratory

What is Non-Destructive Assay?

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- Techniques to measure radiation induced (active) or emitted (passive) spontaneously from nuclear material

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Benefits:

- Eliminates the need for sampling/expending material
- Often fast and inexpensive

Drawbacks:

- Less accurate compared to destructive analysis

Non-Destructive Assay Instruments

Gamma Spectroscopy

Resolution can be Low (Sodium Iodide) or High (High-Purity Germanium)

https://www.ortec-online.com/products/radiation-detectors/germanium-hpge-radiation-detectors

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- Effective matrix density (dimensions, weight)
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Using specific activities, one can determine gram quantity

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Non-Destructive Assay Instruments

Neutron

Can be active (interrogation) or passive measurements

https://www.mirion.com/products/wm3210-passive-active-neutron-cf-252-shuffler-system

https://www.mirion.com/products/jcc-51-active-well-neutron-coincidence-counter

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Measurement systems outfitted with Heliem-3 tubes incased in High-density poly-ethylene (neutron moderator)

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Fission neutrons roll in pairs (or multiples)! Neutrons are time-correlated and used to quantify material

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Calorimetric (heat) measurement to assert total heat output

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Specific power is a *known*

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Isotopics are obtained using gamma spectroscopy (usually)

- Weight percent of isotopes are asserted for the item

Specific power is a *known*

Heat output (measured) + weight percent via isotopics (measured) + specific heat (known) = Quantity

Measurement Control

Measurement control is to:

- Ensure instrument stability
- Minimize uncertainty
- Provide a pedigree for instrument performance

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- 2σ = Warning (95.45% of values found within this limit)
- 3σ = Alarm (99.73% of values found within this limit)

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Visualized with **Control Plot**

#	Standard	Certified Value	Measured Value	Measured/Certified
1	A	25.0000	25.27	1.0108
2	A	25.0000	24.50	0.98
3	A	25.0000	25.24	1.0096
4	A	25.0000	24.76	0.9904
5	A	25.0000	24.00	0.96
6	A	25.0000	25.34	1.0136
7	A	25.0000	25.13	1.0052
8	A	25.0000	24.60	0.984
9	A	25.0000	24.88	0.9952
10	A	25.0000	24.76	0.9904
11	A	25.0000	25.02	1.0008
12	A	25.0000	24.84	0.9936
13	A	25.0000	25.41	1.0164
14	A	25.0000	24.75	0.99
15	A	25.0000	24.73	0.9892
16	A	25.0000	24.97	0.9988
17	A	25.0000	24.83	0.9932
18	A	25.0000	25.02	1.0008
19	A	25.0000	25.90	1.036
20	A	25.0000	24.80	0.992
21	A	25.0000	25.26	1.0104
22	A	25.0000	24.50	0.98
23	A	25.0000	25.17	1.0068
24	A	25.0000	24.51	0.9804
25	A	25.0000	25.16	1.0064
26	A	25.0000	24.90	0.996
27	A	25.0000	24.79	0.9916
28	A	25.0000	25.22	1.0088
29	A	25.0000	25.19	1.0076
30	A	25.0000	24.97	0.9988
31	A	25.0000	24.86	0.9944
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Control Plot Example

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- The control plot will show the measured value with respect to the certified value (i.e. deviation from "*normal*")
- Control plot values are expected to be centered around 1
- Data is used to establish standard deviation (σ) and bias
- Useful in observing *as found* instrument behavior

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Number of Data Points

Should have adequate amount of data to understand instrument behavior

Data should conform to the *central limit theorem*

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Standard ID & Value

Should have unique standard ID

This standard is traceable and established through a superior method

Used as the denominator for the Control Plot ratio

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Measured Value

Measured value (relatively self explanatory)

Used as the numerator in the Control Plot ratio

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Measured/Certified (i.e. Control Plot Values)

Value is unitless (gram/gram, watt/watt, etc)

Shows relationship between the measured vs certified

- 1.1= measured value is higher than the reference value
- 0.9= measured value is lower than the reference value

#	Standard	Certified Value	Measured Value	Measured/Certified
1	A	25.0000	25.27	1.0108
2	A	25.0000	24.50	0.98
3	A	25.0000	25.24	1.0096
4	A	25.0000	24.76	0.9904
5	A	25.0000	24.00	0.96
6	A	25.0000	25.34	1.0136
7	A	25.0000	25.13	1.0052
8	A	25.0000	24.60	0.984
9	A	25.0000	24.88	0.9952
10	A	25.0000	24.76	0.9904
11	A	25.0000	25.02	1.0008
12	A	25.0000	24.84	0.9936
13	A	25.0000	25.41	1.0164
14	A	25.0000	24.75	0.99
15	A	25.0000	24.73	0.9892
16	A	25.0000	24.97	0.9988
17	A	25.0000	24.83	0.9932
18	A	25.0000	25.02	1.0008
19	A	25.0000	25.90	1.036
20	A	25.0000	24.80	0.992
21	A	25.0000	25.26	1.0104
22	A	25.0000	24.50	0.98
23	A	25.0000	25.17	1.0068
24	A	25.0000	24.51	0.9804
25	A	25.0000	25.16	1.0064
26	A	25.0000	24.90	0.996
27	A	25.0000	24.79	0.9916
28	A	25.0000	25.22	1.0088
29	A	25.0000	25.19	1.0076
30	A	25.0000	24.97	0.9988
31	A	25.0000	24.86	0.9944
32	A	25.0000	24.88	0.9952

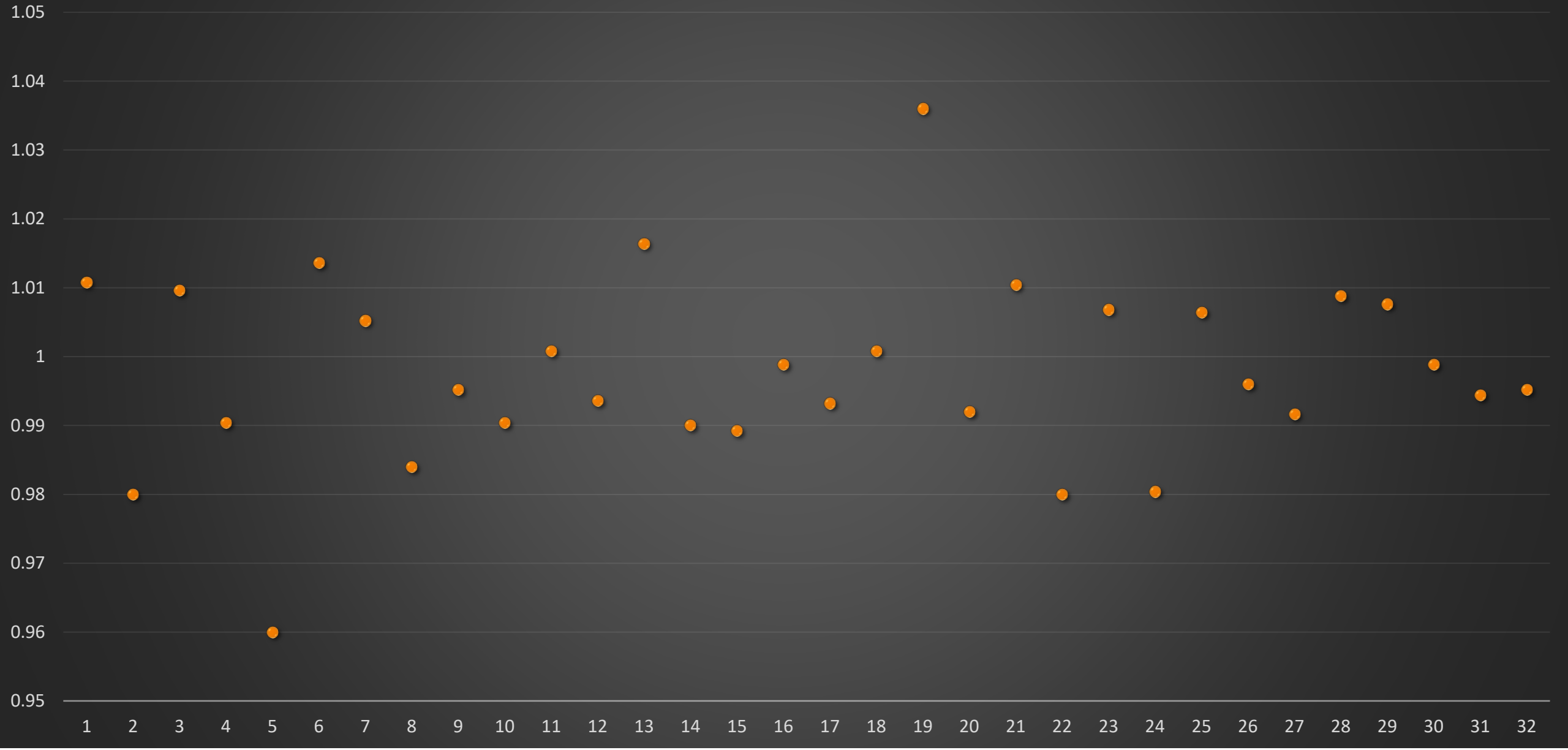
Standard Deviation (σ)	0.013804534
Bias	0.9977

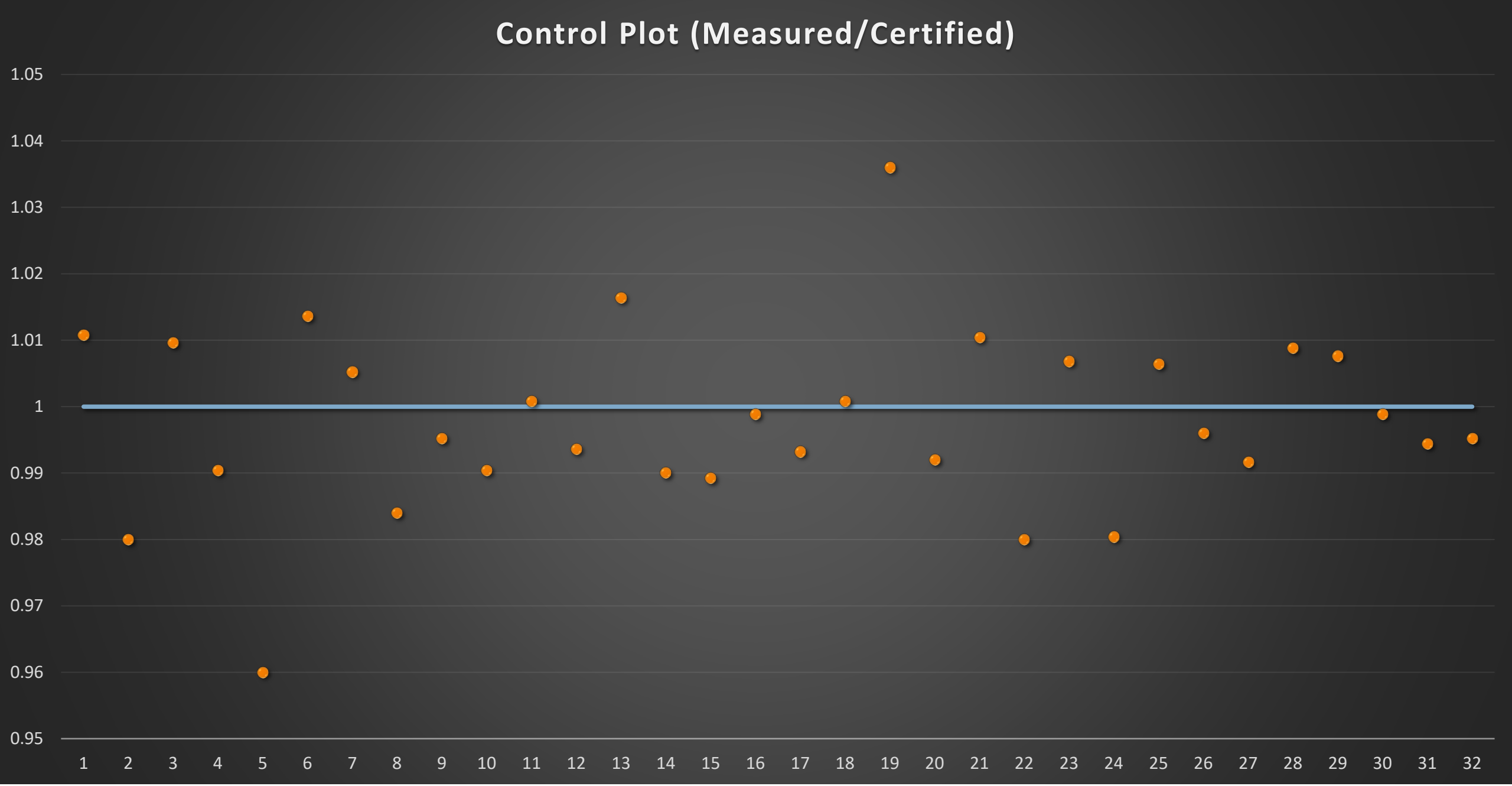
Standard Deviation/Bias

Standard Deviation is basis of control limits

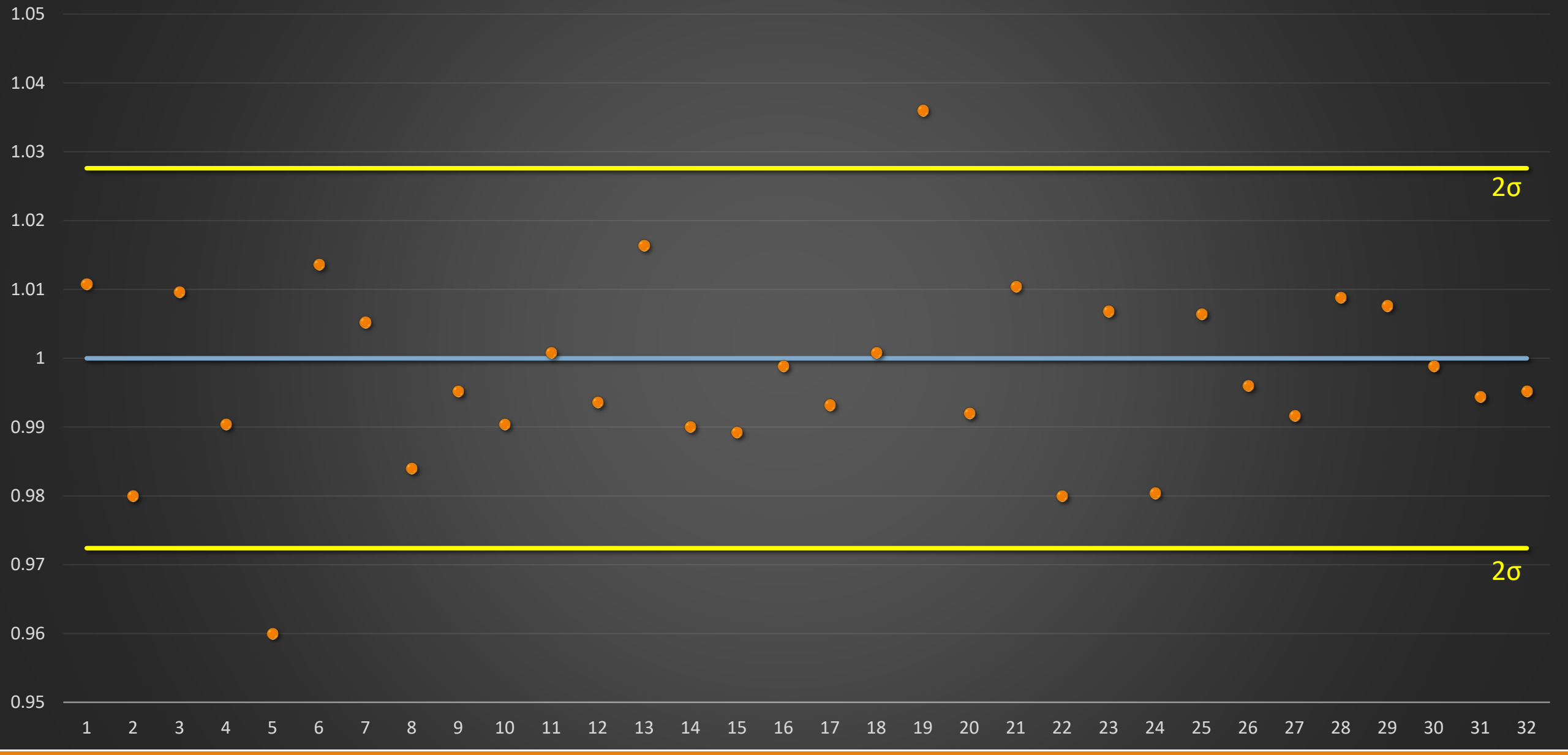
Bias indicates if reality of instrument needs to be adjusted

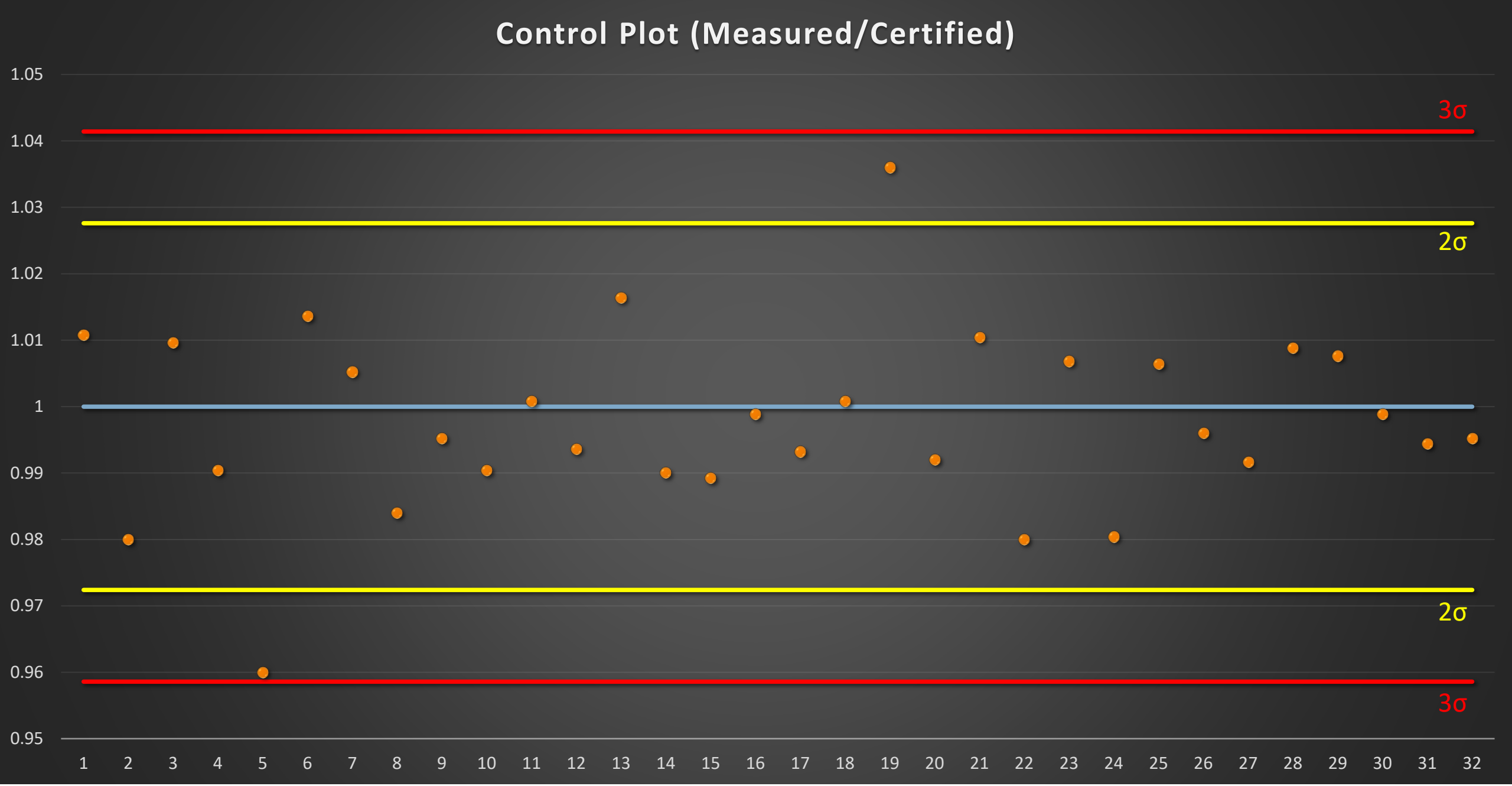
Control Plot (Measured/Certified)

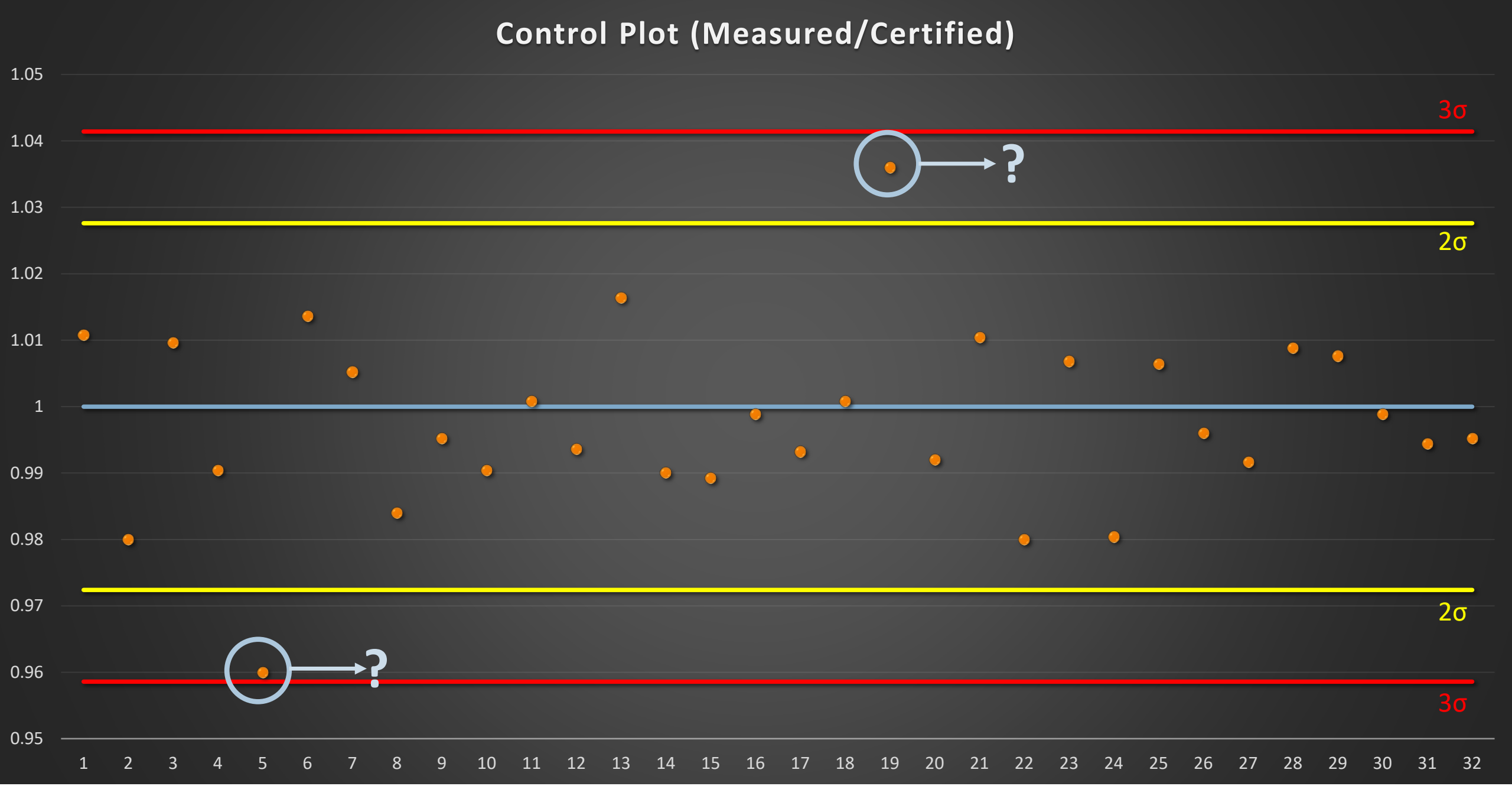



Control Plot (Measured/Certified)
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Control Plot (Measured/Certified)




Control Plot (Measured/Certified)
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
3σ
2σ
2σ
3σ
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32


Control Plot (Measured/Certified)
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
3σ
2σ
2σ
3σ
?
?
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

This is expected!!!

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Some points outside of 2 sigma are expected in a normal data set (**about 5%**)

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Even the occasional random 3 sigma failure (**<1%**) is expected to occur over the lifetime of the instrument

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Even the occasional random 3 sigma failure (**<1%**) is expected to occur over the lifetime of the instrument

This would be considered an issue when **back-to-back** or **2 out of 3 points outside of 2σ**

Other considerations…

Points outside of 3σ or 2σ are **not the only signal** for anomalous data

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Western Electric

Nelson

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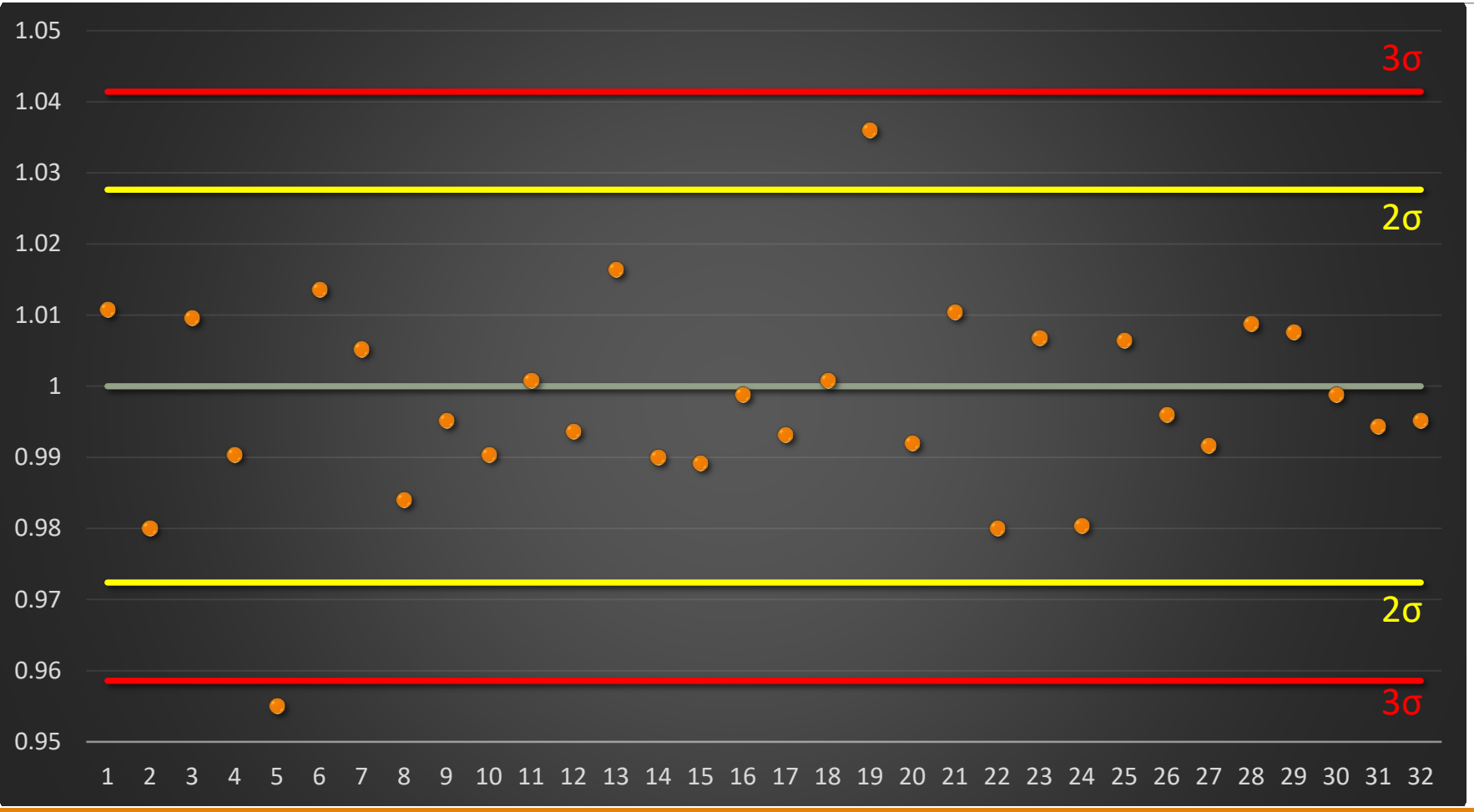
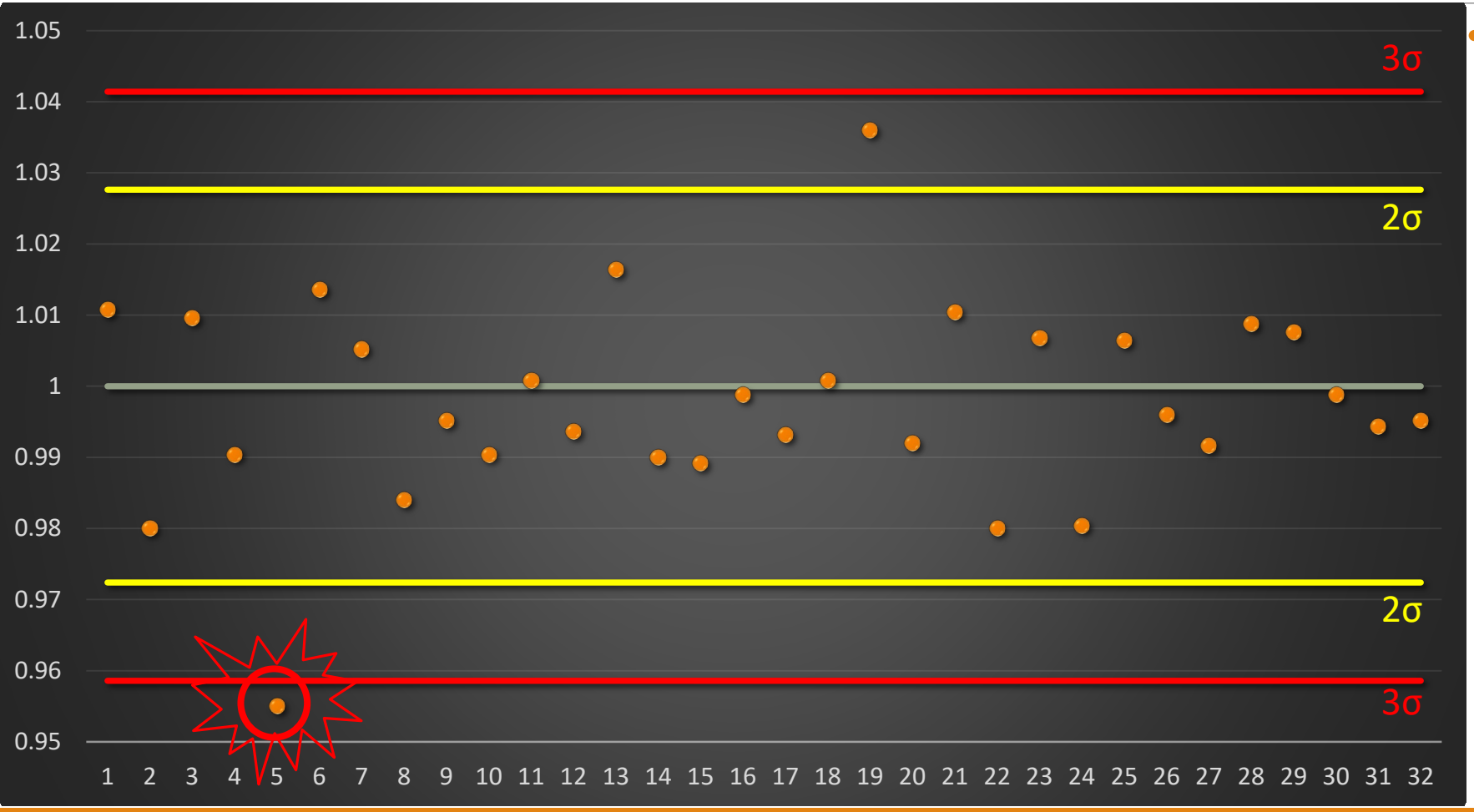
Common Rules and what they imply!

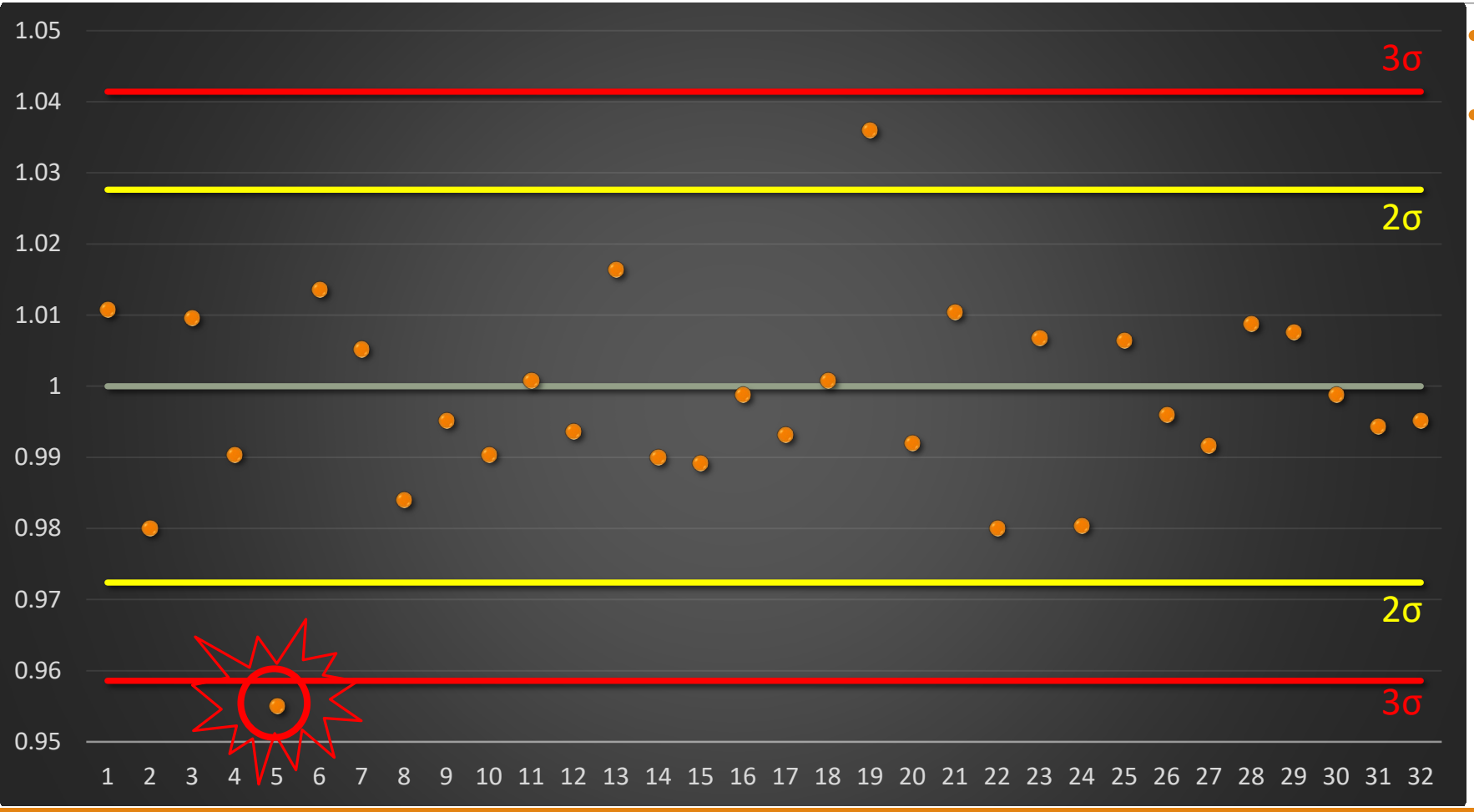


Common Rules and what they imply!



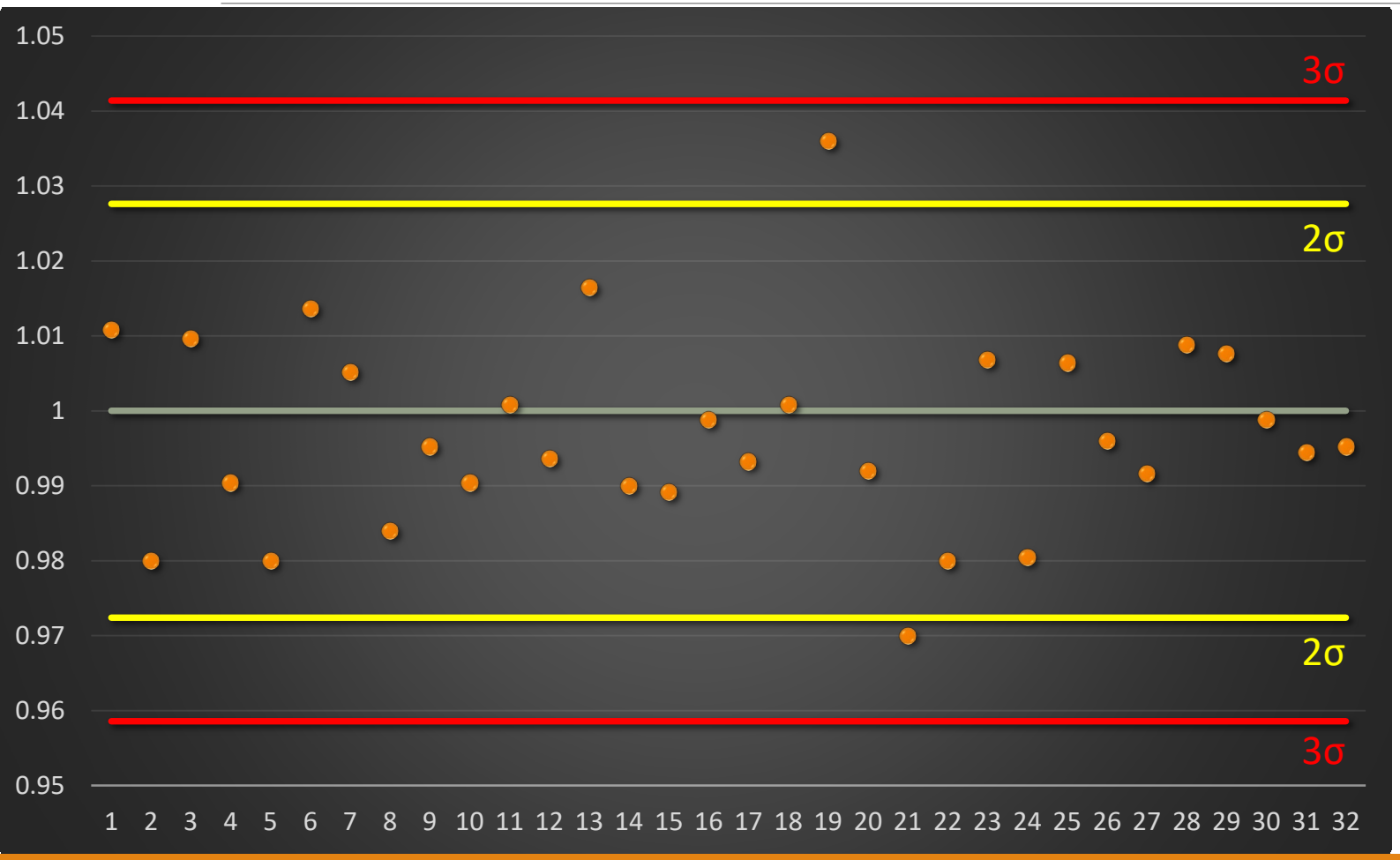
- Single Point outside of 3σ

Common Rules and what they imply!

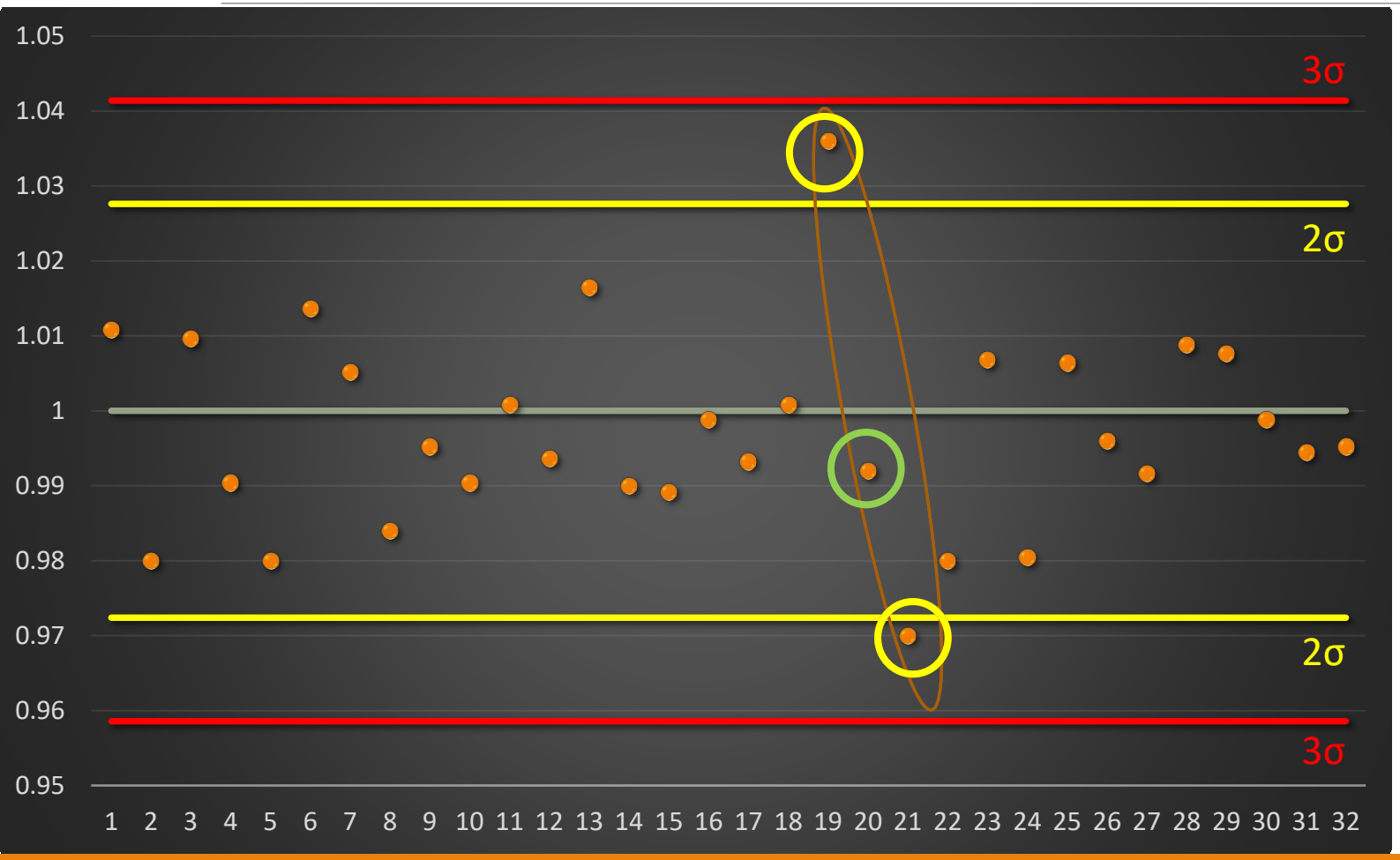


- Single Point outside of 3σ
- Out of Control

Common Rules and what they imply!

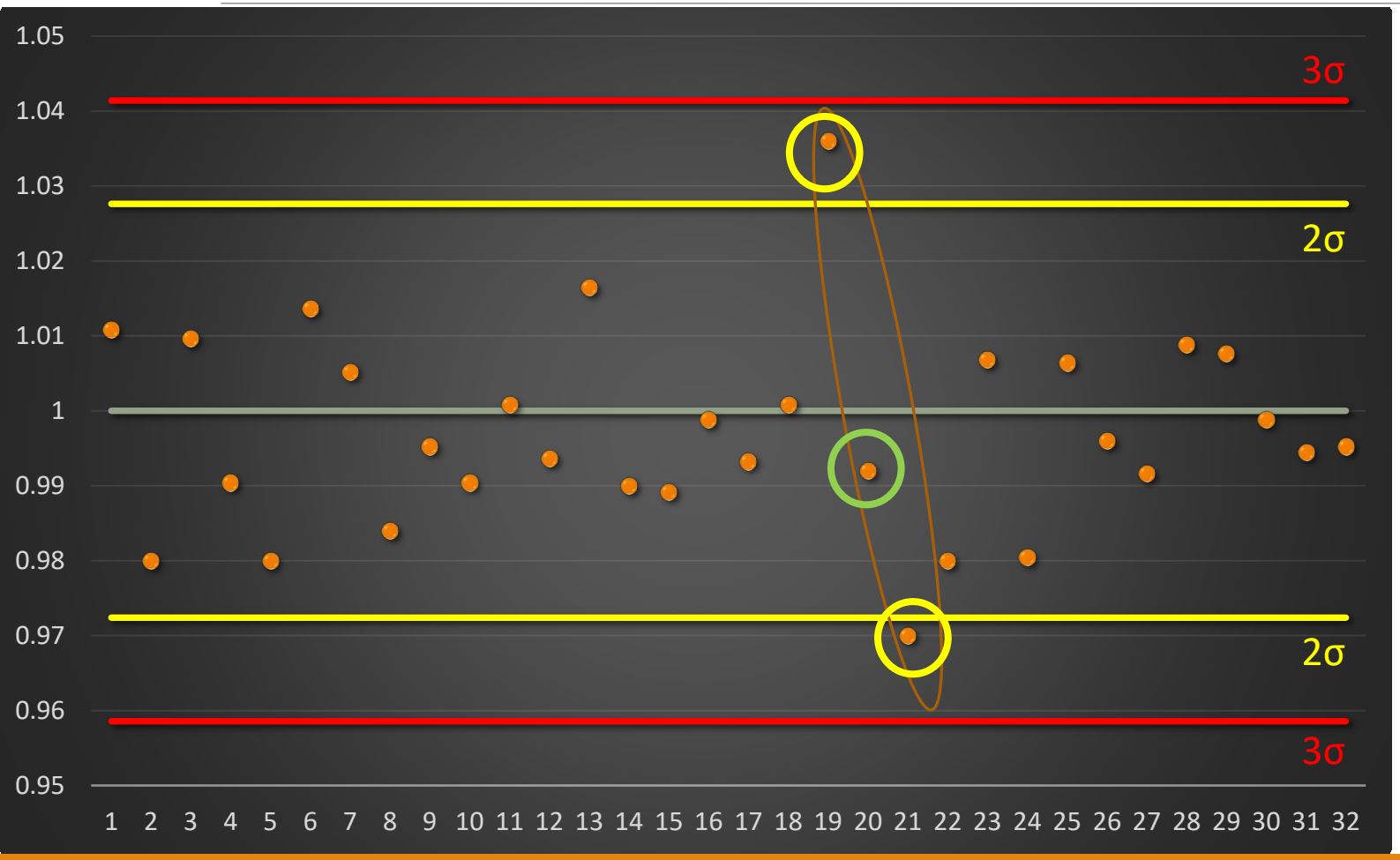


Common Rules and what they imply!



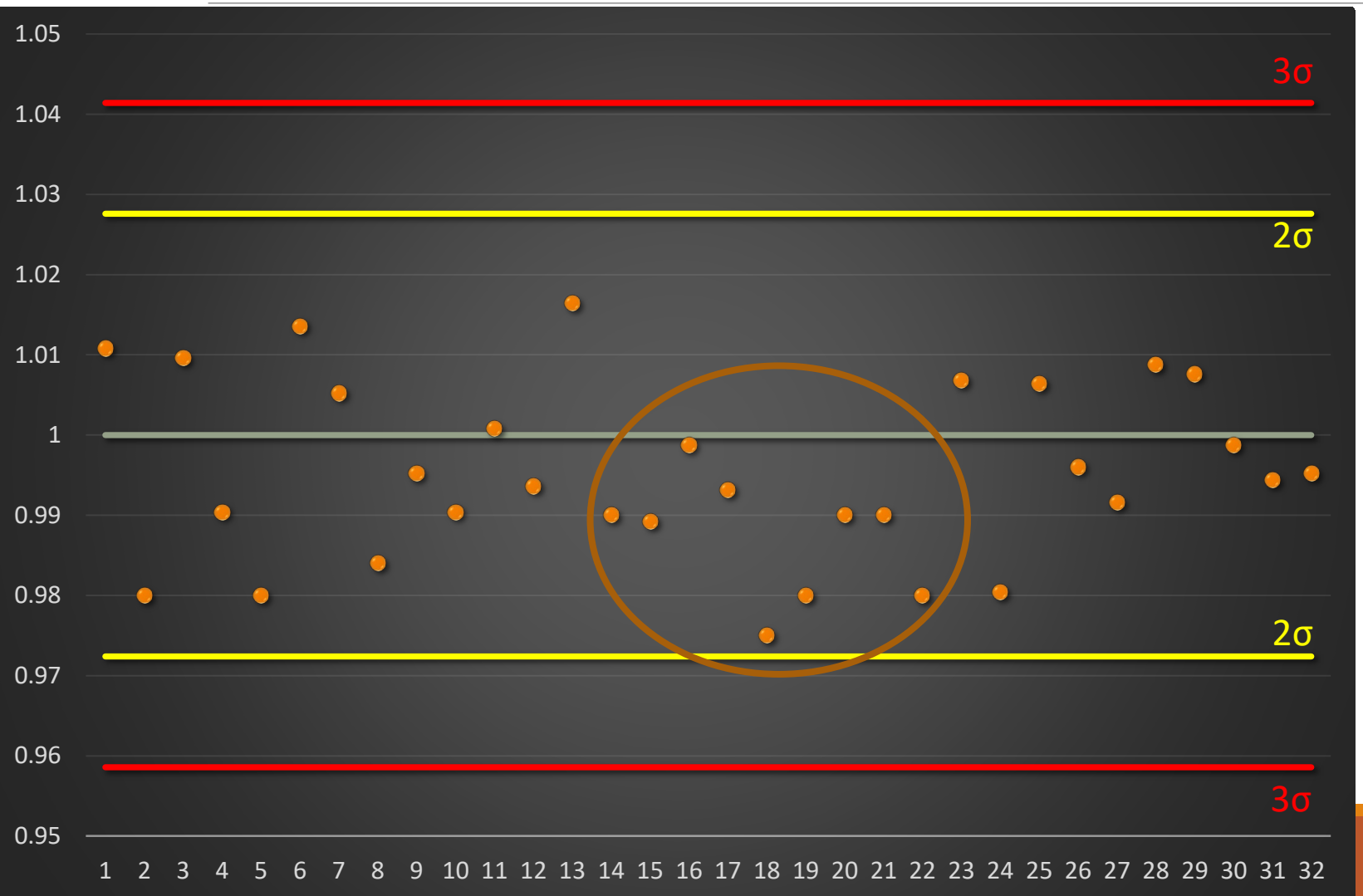
- 2 out of 3 consecutive points outside of 2σ

Common Rules and what they imply!



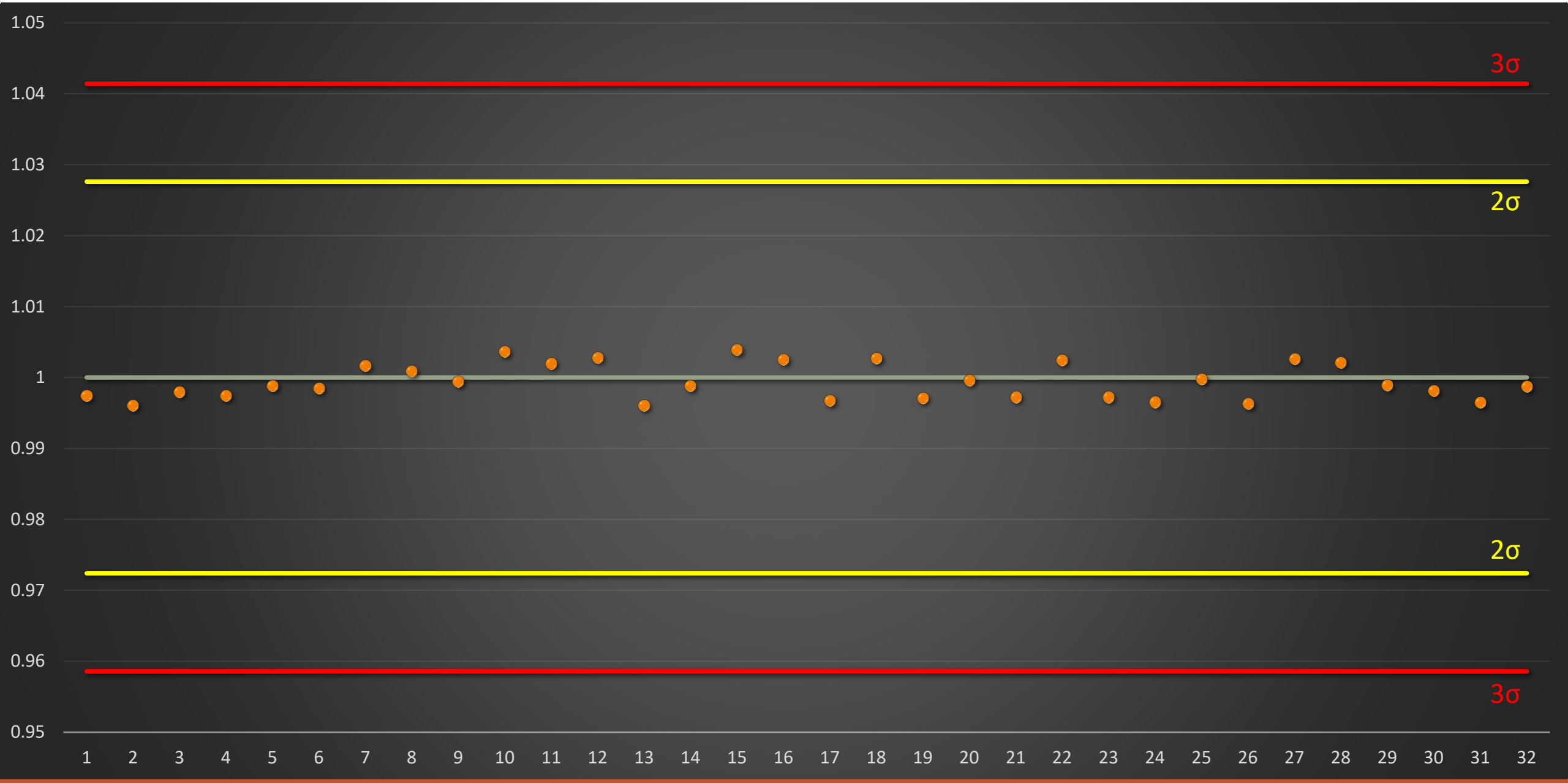
- 2 out of 3 consecutive points outside of 2σ
- Data showing higher frequency being outside of expected confidence intervals

Common Rules and what they imply!



- 9 consecutive data points below/above the mean
- May indicate a prolonged bias

General Data Awareness



How it relates to Safeguards

Values obtained from measurement systems are used to account for nuclear materials!

We must ensure these systems perform within an expected range

Having a high confidence in instrument performance is equal to high confidence material present


DO NOT STAND
ON GLOVEBOXES!
55-12-170-25

Questions?

Wilder Greene

wilder.greene@gmail.com

Nondestructive Assay Resource

PANDA Manual- Fantastic resource for non-destructive assay

https://www.lanl.gov/org/ddste/aldgs/sst-training/Panda%20Manual%20Chapters.php